NASA/CP—2009-215797

NASA Airframe Icing Workshop

FAA Perspective

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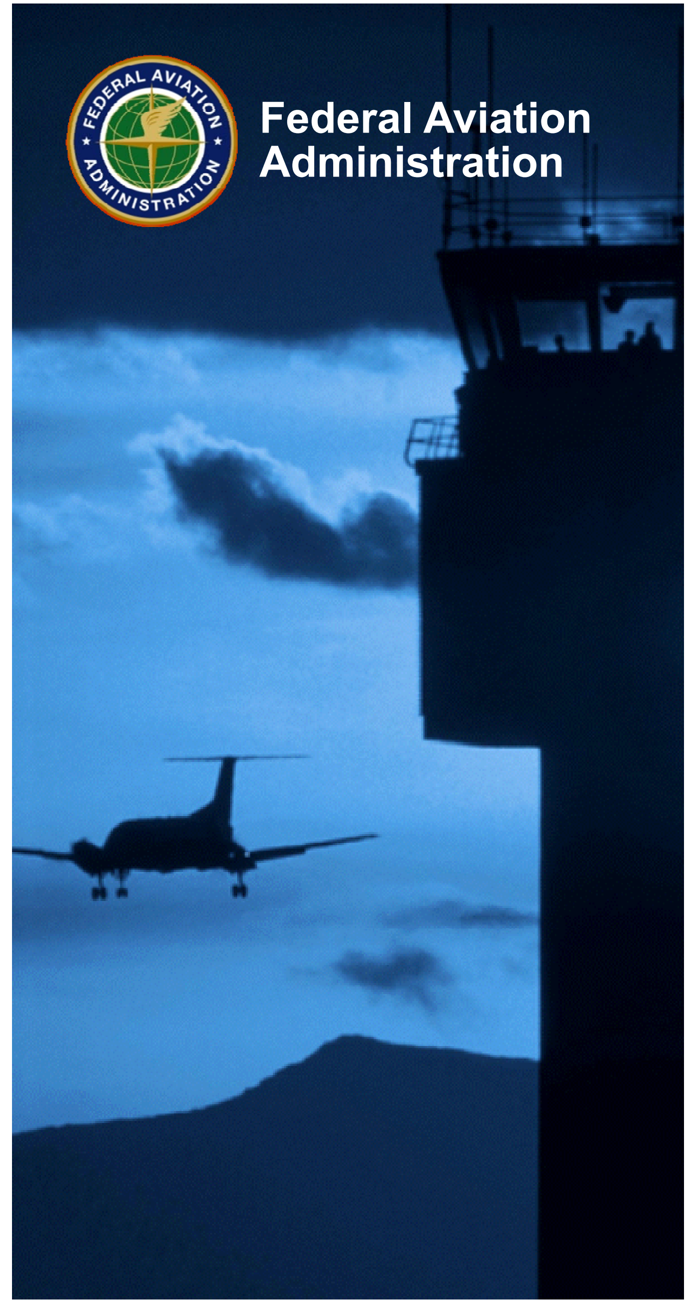

Pitch to NASA (1/3)

- ***Thank you*** **for putting this workshop together**
- **NASA *owns* the U.S. national research expertise in in-flight aircraft icing. It is held in very high regard across the aerospace industry – both here and abroad**
  - The FAA and industry rely on this expertise to
    - Develop new engineering tools to support airworthiness (certification) - experimental and analytical methods
    - Develop benchmark databases
    - Explore the sciences of aircraft icing to understand, model, and simulate the physical mechanisms associated with ice accretion and iced aerodynamics
    - Support and develop icing facilities for R&D and testing

Pitch to NASA (2/3)

- **NASA has a rich heritage in aircraft icing. Working with its academic partners, it has built the fundamental building blocks and the current capabilities for many of the modern experimental and analytical tools used by industry**
  - Icing physics and scaling
  - 2D experimental iced aerodynamics
  - LEWICE CFD tools: regarded as the "gold standard" that others compare to
  - IRT: considered the premier icing wind tunnel for R&D, provides leadership for new simulation practices

Pitch to NASA (3/3)

- **The aerospace community cannot go forward to solve major R&D thrusts in aircraft icing such as turbojet engine ice crystal ingestion, SLD means of compliance, 3-D iced aerodynamics, or other airframe icing research without NASA's leadership**

Please sustain your core competency and level of investment in this area – it is essential to national interests in the development of engineering tools and aviation safety for aircraft icing

Outline

Gap Areas – FAA Perspective:

- **Near Term Need**
  - **SLD Engineering Tools**
- **Intermediate Term Need**
  - **Iced Aerodynamics**
- **Other Gap Areas**
- **Summary**

SLD Engineering Tools

SLD Engineering Tools – History

- **The Ice Protection Harmonization Working Group (IPHWG) was tasked to:**

  Review National Transportation Safety Board recommendations A-96-54, A-96-56, and A-96-58, and advances in ice protection state-of-the-art. In light of this review,

  define an icing environment that includes supercooled large droplets (SLD), and devise requirements to assess the ability of aircraft to safely operate either for the period of time to exit or to operate without restriction in SLD aloft,

  in SLD at or near the surface, and in mixed phase conditions if such conditions are determined to be more hazardous than the liquid phase icing environment containing supercooled water droplets. Consider the effects of icing requirement changes on 14 CFR part 23 and part 25 and revise the regulations if necessary…

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SLD Engineering Tools – History

- **New rulemaking for SLD is in progress. Target for the NPRM release is early 2010. In order to comply, aircraft manufacturers must be able to design for SLD icing conditions and provide "proof of performance" for certification**
- **This requires the capability to simulate SLD icing conditions and have SLD engineering tools (analytical and experimental) and icing facilities that provide means of compliance.**
- **The engineering tools need to determine the properties of SLD ice accretions on airframe components**
  - ***Shape***
  - ***Location and extent***
- **And, determine the effects of these accretions on the airplane flight characteristics**
  - ***Stall speeds***
  - ***Performance & handling qualities***

SLD Research – NASA's Role

- **NASA has provided major R&D resources during the last ~ 10 years. These included:**
  - Icing Branch researchers, GRC facilities engineers and technicians, computer scientists, other on-lab service groups, and university grant expertise
  - Facilities: Icing Research Tunnel, Icing Research Aircraft (Twin Otter), and partnered tasks in a vertical flow tunnel, and dry air wind tunnels (Iowa State computational lab, UIUC, WSU, etc.)
- **NASA developed and made publicly available its research results, CFD tools, test methods, scaling methods, and facilities improvements.**

SLD – Means Of Compliance

- **The IPHWG developed a Working Group Report for SLD, glaciated, and mixed phase icing conditions. It provided a record of the IPH deliberations and draft new rulemaking language. It also highlighted concerns by manufacturers regarding the state-of-the-capabilities of engineering tools for use in SLD means of compliance (MOC)**
- **A draft document was developed to review the MOC and respond to the groups concerns**
  - The IPHWG developed a MOC table to assess the use of current SLD engineering tools to meet the proposed certification requirements
  - The IPHWG evaluated the engineering tools capabilities against the proposed new SLD certification requirements
- **This exercise provided a clear understanding of where weaknesses and lack of performance for the current SLD engineering tools capability exist**

Assessment of SLD Engineering Tools Capabilities

Courtesy of the IPHWG – not yet publicly released

FZDZ – freezing drizzle

FZRA – freezing rain

		Unprotected Areas: Wing	Unprotected Areas: Tail	Unprotected Areas: Radome	Unprotected Areas: Non-lifting Surfaces (antenna, inlets, external modifications)	Protected Areas: Thermal (protected area)	Protected Areas: Thermal (Aft of protected area)	Protected Areas: Mechanical (protected area)	Protected Areas: Mechanical (aft of protected area)	Protected Areas: Fluid Freezing Point Depressant	Detection Methods: Visual Cues (Reference Surface)	Detection Methods: Instrument (position or installation effects)	Detection Methods: Instrument (performance)	Air Data Sensors: Instrument (position or installation effects)	Air Data Sensors: Instrument (performance)
FZDZ MVD < 40µm	Icing Tunnels	Green	Green	Red *	Green	Green	Green	Green	Green	Green	Green / Yellow *	Green / Red *	Green	Green / Red *	Green
	Codes	Green	Green	Yellow	Green / Red **	Green	Red	Red	Red	Green	Green / Yellow **	Green	Red **	Green	Red
	Tankers	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
FZDZ MVD > 40µm	Icing Tunnels	Green	Green	Red *	Green	Green	Green	Yellow	Yellow	Green	Green / Yellow *	Green / Red *	Green	Green / Red *	Green
	Codes	Green	Green	Yellow	Green / Red **	Green	Red	Red	Red	Green	Green / Yellow **	Green	Red **	Green	Red
	Tankers	Red	Red	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
FZRA MVD < 40µm	Icing Tunnels	Yellow	Yellow	Red *	Yellow	Yellow	Yellow	Yellow	Yellow	Green	Red	Red	Red	Red	Red
	Codes	Yellow	Yellow	Red **	Yellow / Red **	Yellow	Red	Red	Red	Yellow	Yellow	Green	Red	Green	Red
	Tankers	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
FZRA MVD > 40µm	Icing Tunnels	Red	Red	Red *	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	Codes	Yellow	Yellow	Red **	Yellow / Red **	Yellow	Red	Red	Red	Yellow	Yellow	Green	Red	Green	Red
	Tankers	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red

LEGEND Updated FEB 2009

Green	The capability exists today and is suitable to be an element of a MOC
Yellow	The capability is possible, but has not been demonstrated, or there is limited or no validation.
Red	The capability is unknown, or does not currently exist

* It may be possible to test small scale installation effects, but large scale installations are not currently feasible

** Current 2D capabilities exist with large droplet effects, but limitations exist in the use of 3D codes for simulation of Appendix X effects

SLD Engineering Tools - Gaps

- **SLD engineering tools capabilities need more R&D**
  - **Incorporate current SLD effects into 3-D CFD codes**
  - **Improve simulation capabilities - replace correlations with physical models where resolution and accuracy increases are warranted**
    - Sensitivity studies to guide research directions
    - Research areas requiring a better understanding: accretion physics and SLD ice feature growth, droplet impact dynamics (splashing, break-up, re-impingement), surface water transport, heat transfer, and roughness formation
  - **Validation database for swept wing airfoils**
  - **Simulation exercises and code evaluation cases to determine use of analytical tools and potential facility test methods (FZRA with MVD < 40 μ) for freezing rain conditions**

3D Iced Aerodynamics

3D Iced Aerodynamics

- **Develop a 3-D iced aero research project to understand the aerodynamic effects of ice accretions on 3-D swept wings and provide a 3-D iced-airfoil public database to support CFD validation**
- **Strategy:**
  - Use extensive experience gained on 2-D iced airfoils R&D and methods developed from the recent NASA-ONERA-UIUC "SUNSET" tests to guide an R&D strategy for 3-D
- **Objectives:**
  - Understand the flow physics and any fundamental differences from the 2-D case
  - Understand aerodynamic performance
  - Establish test techniques, including Re and M effects and scaling
  - Ensure that results are validated by flight-Re data

3D Iced Aerodynamics

- **This research requires significant investments, coordination, and commitment – with shrinking national resources, consider a collaborative partnership with industry and other federal agencies**
  - Bring together expertise and resources for a common pre-competitive research goals
  - Develop an approach for identifying physical phenomena studies, test techniques, and analysis methods
  - Use national research facilities for iced and dry-air wind tunnel tests

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Other Gap Areas

- **There are still other important areas for R&D investment in airframe icing that need to be considered**
  - Development of improved calibration, measurement, and diagnostic tools for facilities for evaluating icing cloud conditions and aircraft/ice surface microphysical phenomena
  - Operations: aircraft state/IPS management/icing weather threat assessment tools → intelligent aircraft systems
  - Design & certification → complete aircraft icing performance tools
- **Fundamental research:**
  - Quantify micro-physical events, both 2-D and 3-D (hydrodynamics, ice growth physics, roughness and heat transfer, and boundary layer phenomena)
  - Icing scaling issues for larger droplet sizes, higher speeds, and larger model scale ranges

Summary

- **The two most important areas from the FAA perspective for airframe icing are:**

1. **Continued improvements in SLD engineering tools to meet concerns about MOC**
2. **3-D iced aerodynamics – recognizing this will require a substantial collaborative investment to understand 3-D ice accretions and their attendant effects on swept wing aerodynamics**

QUESTIONS?